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THE EFFECTS OF SUCCESS RELATED PRESSURE ON INFORMATION PROCESSING STRATEGIES AND PLAN CONTINUATION ERROR

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An experiment was conducted to explore whether plan continuation errors could be explained by two types of perseveration behaviours: Perseveration in a wrong Representation of the Situation (PRS) and Perseveration in a risky Plan of Action (PPA). Effects of success-related pressure and flight phase on pilots performance were also examined. Six scenarios were created where expected or unexpected threats had to be managed. Pilots chose between three plans of actions corresponding to PPA, PRS and Flexibility. Results showed that the two types of perseveration could effectively explain plan continuation errors even though PPA characterised cruise phase and PRS was more frequently chosen when managing threats during the approach phase. An effect of success-related pressure was observed as pilots experiencing high pressure were more flexible than pilots experiencing low pressure.

Plan continuation error or *bias* is an essential component of numerous aeronautical accidents. It occurs when pilots fail to revise an original flight plan despite emerging evidence that suggests it is no longer safe and that a new plan is required (Orasanu, Martin & Davison, 2001). An analysis of accidents reports revealed that nearly two-thirds of decision errors can be classified as plan continuation errors (NTSB, 1994). Moreover, a European safety study showed that between 1991 and 1996, 41.5% of fatal accidents in general aviation were due to perseveration on landing under degraded meteorological conditions while they only represent 4.5% of all accidents (Bureau d'Enquêtes et d'Analyses, 1997). This inability to adapt to changes in the environment which leads to human error can also be related to a general behaviour called *perseveration* and defined in psychology as "the difficulty experienced in switching from one pattern of behaviour or method of working to another" (Coleman, 2001), as opposed to *flexibility*. This being so, perseveration may be observed in a large number of accidents such as a meteorologically changing context or the management of technical failures and may occur at any moment in the flight plan. For example, in military aviation, some accidents occurred when pilots persevered in applying check-lists whose items did obviously not match with the current situation. It is then essential to identify the underlying cognitive processes and factors that impair this decision making process.

Models of aeronautical decision making describe three main processes which are: information perception, elaboration of a mental representation of the situation and selection of a plan of action. Plan continuation error may result from any of these three processes. When an important cue relative to a threat is not perceived or is not interpreted as a threat, the pilot representation of the situation is inaccurate, leading to an inadequate plan of action (Goh & Wiegmann, 2001; Wiegmann & Shappell, 1997). When it is perceived and properly interpreted as a threat, a plan continuation error may still occur if pilots underestimate the risk level associated with the continuation of their action plan and/or they overestimate their capacity to control the situation (Orasanu, Fisher & Davison, 2002; Goh and Wiegmann, 2001). Hence, plan continuation error could be explained by two types of perseveration behaviour: 1) Perseveration in a wrong Representation of the Situation (PRS) and 2) Perseveration in a risky Plan of Action (PPA). Moreover, many reports of accidents happening during the landing phase revealed that pilots made continuation plan errors even though they were aware early on of the deterioration of weather conditions at the destination field. Hence, plan continuation error can occur while changing flight conditions are expected and anticipated. This behaviour may be explained by the PPA type of perseveration where relevant information is perceived and well interpreted but where pilots fail to assess the risk level related to their plan of action. Yet, most studies dealing with plan continuation errors in flight simulation do not manipulate the threat expectancy factor and only refer to unexpected threats. One goal of our study was to verify whether these two types of perseveration could be observed in plan continuation errors and especially by comparing flight situations with expected vs. unexpected threats.

Additionally, while most studies on aeronautical decision making were conducted with commercial aircrews, fewer have been realized with military aircrews (Denihan, 2007; Sicard, Taillemite, Jouve & Blin, 2003). Yet, in this particular domain, flight situations can result in a high degree of complexity due to specific and sometimes hazardous missions (Prince & Salas, 1993). Flying the aircraft may become a secondary task compared to the mission related task (Sicard *et al.*, 2003). In this context, organizational pressure may be very

high and expressed in the form of pressure to succeed with the mission. A study by Denihan (2007) revealed that naval aviators acted in ways designed to foster their combat mission success over safety. Indeed, interviews of 11 pilots showed that cues related to reducing risk level and considered in the decision making process during non-combat missions were not considered during combat missions. Hence, organizational pressure may increase conflict between mission-related goals and safety-related goals. Yet, in a commercial flight simulation experiment using think-aloud protocols, external pressures represented only 4.2 percent of pilots talk (Orasanu, Fisher & Davison, 2002). Analysis of military pilot decision making could be of interest in determining how organizational pressure can have an impact on plan continuation error. The context of flight in the face of a threat is also an important component of plan continuation errors. An analysis of accident reports showed that plan continuation error is more frequent during approach and landing than during other phases of flight (Orasanu, Martin & Davison, 2001). Still, results from a study conducted in a simulation session where pilots encountered adverse weather did not support this finding (Wiegmann, Goh & O'Hare, 2002). On the contrary, unlike pilots who encountered adverse weather late during the flight, the majority of pilots who faced this event early during the flight decided to continue in accordance with their original flight plan. This result was explained by the authors as the need and the possibility for pilots to verify their assessment of the situation. In our study, we examined the impact of flight phase using various types of threats, such as deteriorating weather conditions, technical failure and external threat.

The purpose of this study was to verify three main hypotheses. First, we hypothesized that plan continuation errors would be explained by two types of perseveration behaviours: Perseveration in a wrong Representation of the Situation (PRS) and Perseveration in a risky Plan of Actions (PPA). On one hand, we expected that PRS would be characterised by wrong diagnosis and PPA by accurate diagnosis. On another hand, we expected that when threats are expected by pilots, plan continuation error should be explained by PPA while when threats are unexpected, plan continuation error should be explained by PRS. Second, we expected that a high organizational pressure would lead to plan continuation error while low organisational pressure would lead to flexibility. Finally, we expected that flight phase would impact decision making processes where the approach phase should lead to more plan continuation error than take-off and cruise phases.

Methods

Participants

Twenty pilots (19 men, 1 woman) from the French Air Force squadron specializing in the transportation of government authorities participated in the study. In flight hours, the participants' total flight experience ranged from 800 to 7,000 hrs and their mean total flying experience was 3442 hrs ($SD = 1433$ hrs). They ranged in age from 28 to 38 years with a mean age of 33 years ($SD = 3$ years). Participation in the study was on a voluntary basis with complete anonymity of the personnel.

Procedure

Participants were first asked to fill out a biographical questionnaire including information regarding their age and their flight experience. They were then given the experiment instructions and started the training session. When they felt comfortable with the use of the interface, they could start the experimental session. The latter was composed of three screens: 1) description of a flight situation (current coordinates of the flight) with contextual information (nature of the mission, flight plan, meteorological conditions, fuel level). Pilots were asked to build a mental representation of the situation and to click on the next stage only when they felt ready. They were informed that from this moment a stopwatch was started; 2) graphic interface representing the cockpit panel. Pilots could click on any instrument or messages they needed to be able to make a decision between three choices of action. Next, they had to complete a confidence level scale from 1 (no confidence in the decision made) to 5 (extremely confident in the decision made); 3) finally, they were asked to write down what elements influenced their decisions and what were the goal(s) they wanted to reach.

Graphic interface

The experiment was conducted with a laptop using the software "E-Prime". This software enables recording of all the actions made by the participants. Hence, analysis of decision making processes was possible with the creation of a specific graphic interface showing the front panel of a A319 cockpit (figure 1). Pilots clicked on a particular instrument to bring up a small information window displaying the information usually provided by this instrument. Additional links were displayed on the side of the panel providing information from Co-pilot, Air Traffic Controller and Cabin Crew. Pilots could open only one window at a time. Participants practiced on a training session until they felt comfortable with the set-up.



Figure 1. Graphic interface used in the experiment representing an A319 panel. All shaded rectangles could be clicked by participants.

Flight scenarios

Six scenarios were created for the study in collaboration with two pilots who were experts in human factors. They were designed in such a way that each flight situation was ambiguous and where the decision could only be made by the judgment of the pilot with no need for a check-list. Moreover, the threats illustrated by our scenarios had all been involved in incidents or accident databases. The six scenarios reflected three variables employed in this experiment. Threat Expectation (expected threat vs. unexpected threat) and Flight Phase (take-off, cruise, approach) were within-subject variables. Success-Related Pressure (high success-related pressure vs. low success-related pressure) was a between-subjects variable. For the *expected threat* condition, three of the scenarios were conceived such that a potential threat was presented in the first description of the flight situation whereas in the three *unexpected threat* scenarios no potential threat was initially presented. Additionally, each of these conditions occurred during either the take-off, cruise or approach phases of flight. Each participant responded to the six scenarios in random order. Organizational pressure was studied through success-related pressure which was manipulated by the nature of the mission presented at the beginning of the flight situation description. Pilots in the *high success-related pressure* condition had to convey important government authorities whereas pilots in the *low success-related pressure* condition had to convey neutral passengers. Flight plans were the same under both conditions.

Measurement of performance

Three plans of action were presented to participants as a decision choice. They could either divert the flight judging the situation to be much too risky, or they could continue according to the initial flight plan while monitoring flight parameters because of a high risk level, or finally they could continue according to the initial flight plan judging there was no associated risk. These 3 choices corresponded to the perseveration categorizations: Flexibility, PPA and PRS. For ANOVA analyses purpose, these responses were encoded into a numerical variable respectively as 3, 2 and 1, from the most appropriate decision to the least appropriate one. Information processing was analysed through 3 indicators: amount of information accessed, amount of target information accessed related directly to the threat and time spent reading target information as an indicator of the importance of the information for decision making. Finally, participants had to write down all cues that played a role in their decision choice and what goals they wanted to reach. These data were analysed with an *a posteriori* grid coding for building cue categorization and assessing accuracy of the diagnosis.

Results

Decision performance

In order to verify if plan continuation error could be explained by two types of perseveration, we analysed the distribution of the nature of the decision made by participants. Results showed that plan continuation errors were committed on 64 of 120 or 53% of decisions and flexible decisions were taken on 56 of 120 or 47% of decisions. On the 64 plan continuation errors, 48 were PPA or 75% and 16 were PRS or 25%, $p(\chi^2) < .05$. When examining the distribution of the two types of perseveration as a function of Threat Expectancy, results showed that when threats are expected 27 plan continuation errors on of 31 or 87% were explained by PPA and 4 of 31 or 13% were explained by PRS. When threats were unexpected by pilots, 21 of 33

or 64% of plan continuation errors were explained by PPA and 12 of 33 or 36% of plan continuation errors were explained by PRS, $p(\chi^2) < .05$. The distribution between flight phases also showed a significant difference between take-off and cruise phases ($p(\chi^2) = .05$) and between cruise and approach phases ($p(\chi^2) < .05$). Indeed, when threats were managed during the cruise phase, none of the plan continuation errors was explained by a PRS, whereas during the take-off phase 3 of 16 or 19% were explained by PRS and during approach phase 13 of 38 or 34% were explained by PRS.

Effects of Success-Related Pressure, Threat Expectation, Flight Phase and their interactions on decision performance were then analyzed with ANOVAs. Performance was significantly influenced by Threat Expectation ($F(1, 18) = 4.69, p < .05$) and by Flight Phase ($F(2, 36) = 55.7, p < .001$) but not significantly influenced by Success-Related Pressure ($F(1, 18) = 2.53, p > .10$). On one hand, performance was better when threats were expected than when they were unexpected and on the other hand, performance was better during take-off and cruise phases than during approach. The effect of Success-Related Pressure was observed in interaction with Threat Expectation ($F(1, 18) = 9.12, p < .05$): when threats were expected, success-related pressure had no significant impact on performance ($F(1, 18) = 0.72, p > .10$) whereas when threats were unexpected pilots under high success-related pressure performed better than pilots under low success-related pressure ($F(1, 18) = 11.27, p < .05$). Interaction between Success-Related Pressure and Flight Phase was not significant nor was interaction between Threat Expectation and Flight Phase.

Information processing

ANOVAs were conducted for the three independent variables on the amount of information accessed, the amount of target information accessed and the time spent on reading target information. A significant effect of Flight Phase was found on the amount of information accessed ($F(2, 36) = 5.6, p < .05$) where the later threats happened during flight, less information was accessed: around 16 data (± 1.5) were accessed during take-off phase, around 12 data (± 1.4) were accessed during the cruise phase and around 10 data (± 1.3) were accessed during the approach phase. No significant effects were found for Success-Related Pressure, Threat Expectation nor for their interactions. ANOVAs conducted on the amount of target information accessed revealed no significant effect for any of the three variables nor for their interactions. The results of the analyses of time spent reading target information showed only one significant effect of the interaction between Threat Expectation and Flight Phase ($F(2, 36) = 6.35, p < .05$). During take-off and approach phases, time spent reading target information was not significantly different as a function of threat expectancy whereas during the cruise phase, pilots spent more time reading target information when threats were unexpected than when they were expected. Relations between indicators of information processing and the nature of the decisions were analysed using Spearman correlations. No significant effect was found for any information processing indicators since all correlations were close to 0.

Decision cues, diagnosis accuracy and goals to achieve

In order to identify which information was taken into account for decision making, pilots had to give a written account, explaining how they made their decisions and what goals they wanted to achieve. All texts were then classified into: decision making cues, accuracy of diagnosis and goals. Of the 120 decisions made during this experiment, target information was mentioned in 60 decisions (50%), while target information was not mentioned in the 60 others (50%). Distribution among pilots experiencing high success-related pressure and those experiencing low success-related pressure showed that 67% of pilots with high success-related pressure mentioned target information whereas only 33% of pilots with low Success-related pressure mentioned it, $p(\chi^2) < .001$. The link between the number of decisions where target information was mentioned with the nature of the decision taken showed that 71% of flexible decisions were explained with target information whereas only 33% of decisions leading to plan continuation errors were explained with target information, $p(\chi^2) < .001$. On the other hand, no significant difference was found between PPA and PRS, where 37% of PPA decisions were explained with target information for 19% of PRS decisions.

The distribution of diagnosis accuracy with nature of decisions showed a significant difference: 78% of flexible decisions were associated with an accurate diagnosis and for 22% of them no diagnosis was expressed while only 45% of decisions leading to plan continuation errors were associated with accurate diagnosis and 22% of them were associated with a wrong diagnosis, $p(\chi^2) < .001$. Furthermore, 50% of PPA decisions were associated with accurate diagnoses and 17% with wrong diagnoses while only 19% of PRS decisions were associated with accurate diagnoses and 50% of them were associated with wrong diagnoses, $p(\chi^2) < .05$.

Goals to be achieved that were mentioned by participants could be classified into 4 categories: 80% were about maintaining the safety level of the aircraft, 13% were about ensuring that passengers could arrive at their destination, 4% were about maintaining the safety level of passengers and/or aircrew, and 3% were about ensuring effective organization of aircraft repair. The distribution among pilots with a high success-related pressure and low success-related pressure revealed a significant difference ($p(\chi^2)=.05$): 90% of goals mentioned by pilots with low success-related pressure were about aircraft safety levels and 5% concerned the assurance that passengers could arrive at destination while they represented respectively 71 % and 20% for pilots with a high success-related pressure.

Discussion

Our first hypothesis was that plan continuation error could be explained by two types of perseveration behaviour: PRS which describes plan continuation error as committed from a wrong representation of the situation and PPA which describes plan continuation error as committed from an accurate representation of the situation but with a risky choice of action. This hypothesis was verified since both types of perseveration were chosen by participants as the right plan of actions to make when faced with flight threats. Moreover, the link with diagnosis accuracy confirmed that a majority of PPA decisions were characterised by accurate diagnosis while a majority of PRS were characterised by wrong diagnosis. Yet, no difference in the amount of target information mentioned as decision cues was found between PPA and PRS. This may be explained by the fact that several participants did not mention any decision cues at all, even though it is probable that they did take into account some information when making their decision. Additionally, PPA decisions were chosen more frequently to counter flight threats than PRS. Plan continuation errors would then seem to be more frequently due to a difficulty with anticipating the risk associated with a plan of action than a difficulty with assessing the current situation. Yet, our results showed that as a function of threat expectancy, the two types of perseveration are distributed differently. A more important part of plan continuation errors are explained by PRS when threats are unexpected than when threats are expected. This confirms our categorisation of plan continuation errors, since PRS characterizes a wrong representation of the situation and when threats are unexpected it takes more cognitive resources to build an accurate representation of the situation than when threats are expected. Hence, the difficulty encountered by pilots when threats are expected is more about choosing a safe plan of action whereas when threats are unexpected the difficulty is more about finding cognitive resources in order to build a correct representation of the situation.

Our second hypothesis was not verified since pilots with high success-related pressure chose more flexible decisions than plan continuation decisions and inversely for pilots with low success-related pressure. The effect on performance was significant when the threats to be managed were unexpected. Hence, when threats are anticipated pilots may have enough cognitive resources to anticipate flexible solutions whatever the type of pressure. On the contrary, when threats are unexpected pressure has an impact on the decision made by pilots. The presence of important authorities on board seemed to push pilots to privilege safety over mission success. This result is at the opposite of those found by Denihan (2007) where naval pilots on combat mission would rather foster mission success over safety. A bias in the experiment may explain this difference: because pilots had important passengers on board, they could have been tempted to show that this had no influence on their decision. Indeed, results showed that pilots with a low success-related pressure wanted to achieve more safety-related goals than pilots with high success-related pressure who were more concerned about ensuring that their passengers could arrive at destination. Yet, pilots with high success-related pressure mentioned more frequently target information directly linked to threats to be managed than pilots with low success-related pressure, which confirms that pilots with high success-related pressure may have built a better representation of the situation which could explain their better decision performance.

Finally, our results confirmed our third hypothesis that the context of the flight, illustrated here by flight phase also has an impact on plan continuation errors. As expected, performance was better during take-off and cruise phases than when threats happened during the approach phase. In this phase, PRS was most chosen while during the cruise phase plan continuation errors were only explained by PPA. This result suggests that when pilots commit plan continuation errors during approach it could be more due to a difficulty in building an accurate representation of the situation than to a deliberate choice of actions. Indeed, our results showed that the frequency of PRS is in accordance with flight phase workload. The heavy workload of the approach phase could hinder pilots in building an accurate representation of the situation leading to a PRS type of plan continuation error. This result is also supported by the fact that it was during the approach phase that pilots accessed the least amount of information. This result meets those found by Muthard and Wickens (2003) who showed the effect of workload on plan continuation errors in the context of the use of automation.

In conclusion, this study confirmed that plan continuation errors can be explained by two types of perseveration behaviours: Perseveration on a wrong Representation of the Situation (PRS) and Perseveration on a risky Plan of Actions (PPA). This distinction is important to make, since recommendations concerning how to recover from them will focus on different aspects such as specific training in simulator for improving information processing or providing techniques to help pilots to better estimate risks associated with a plan of actions. Finally, success-related pressure illustrated here by the presence on board of important passengers seems to improve decision performance. Yet, further research is needed to complete these findings and eliminate possible bias.

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